Angled Multimode Connectors and PAM4 Signaling

E. Parsons, CommScope

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IEEE 802.3db Ad Hoc Call

25 Jun 2020

Supporters and their affiliation

- Zuowei Shen, Google
- Tiger Ninomiya, Senko
- Sharon Lutz, US Conec
- Ramana Murty, Broadcom
- Mabud Choudhury, OFS

Overview

- Contributions to Next Generation MMF Study Group made a case for APC for 400G-SR8
- Relative cost of cables with angled vs. flat connectors is the same
- Present data from 50G PAM4 experiments to inform decisions for 100G PAM4 and .3db objectives
- UPC connectors do support SR8 transmission if they are standards-compliant (i.e. are clean and have compliant endface geometry)
- UPC connectors with low RL due to air gap can degrade system performance
- Using APC connectors reduces the risk of poor performance by offering higher return loss (RL), even in the presence of an air gap
- More details in: E. Parsons, G. Gibbs, M. Kadar-Kallen, T. Bolhaar, R. Patterson, and J. Young, "Angled 16 Fiber MPO Connectors for 400G-SR8 Applications," Charlotte, NC, IWCS 2019.

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Technical Feasibility of 400G SR8

- 100m OM3 reach with KP4 FEC (2e-4) has been demonstrated with PAM4 VCSEL and 25G NRZ VCSEL.
- VCSELs are available. More PAM4 VCSEL are being developed.
- Linear TIAs and PDs are available.
- VCSEL driver or CDR direct drive have demonstrated performance
- Stronger EQ helps bring down BER floor
  - Tx EQ: compensate VCSEL nonlinearity
  - Rx EQ: recover stressed eye over fiber.
- Use MPO16(1x16) APC to reduce MPI penalty. It is proven that lower link BER can be achieved with APC.
- Suggest to add optical return loss spec to mitigate MPI penalty

Zuowei Shen, employed and affiliated with Google, made case for angled connectors for 400G-SR8

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Technical feasibility

- 100m OM3 reach with KP4 FEC (2e-4) has been demonstrated with PAM4 VCSEL and 25G NRZ VCSEL.
- Leverage 50GbE Electrical I/O specification.
- Define optical specification for 400G-SR8

Example: 50G PAM4 B2B BER and BER over 100m OM3 fiber

- Slight linear offset at high BER
- Possible error floor?
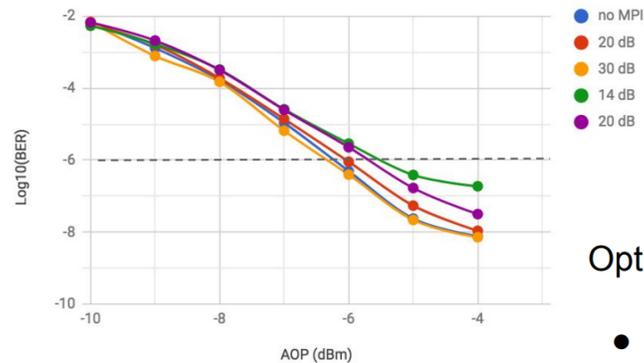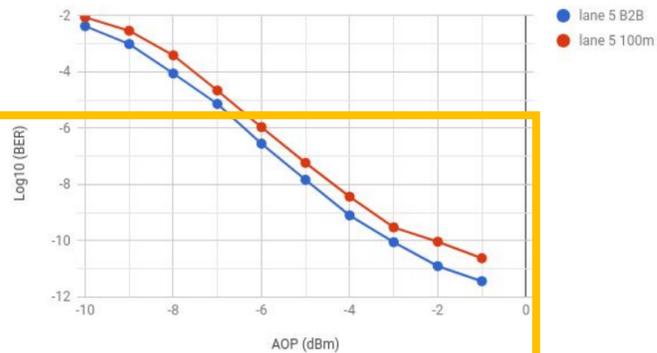
Optical return loss needs to be specified at both Tx and Rx

- 0.7dB penalty with 20dB MPI @1e-6

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MPO ferrule is one of many cable parts

- Long term, negligible cost difference between cables with angled connectors and flat connectors
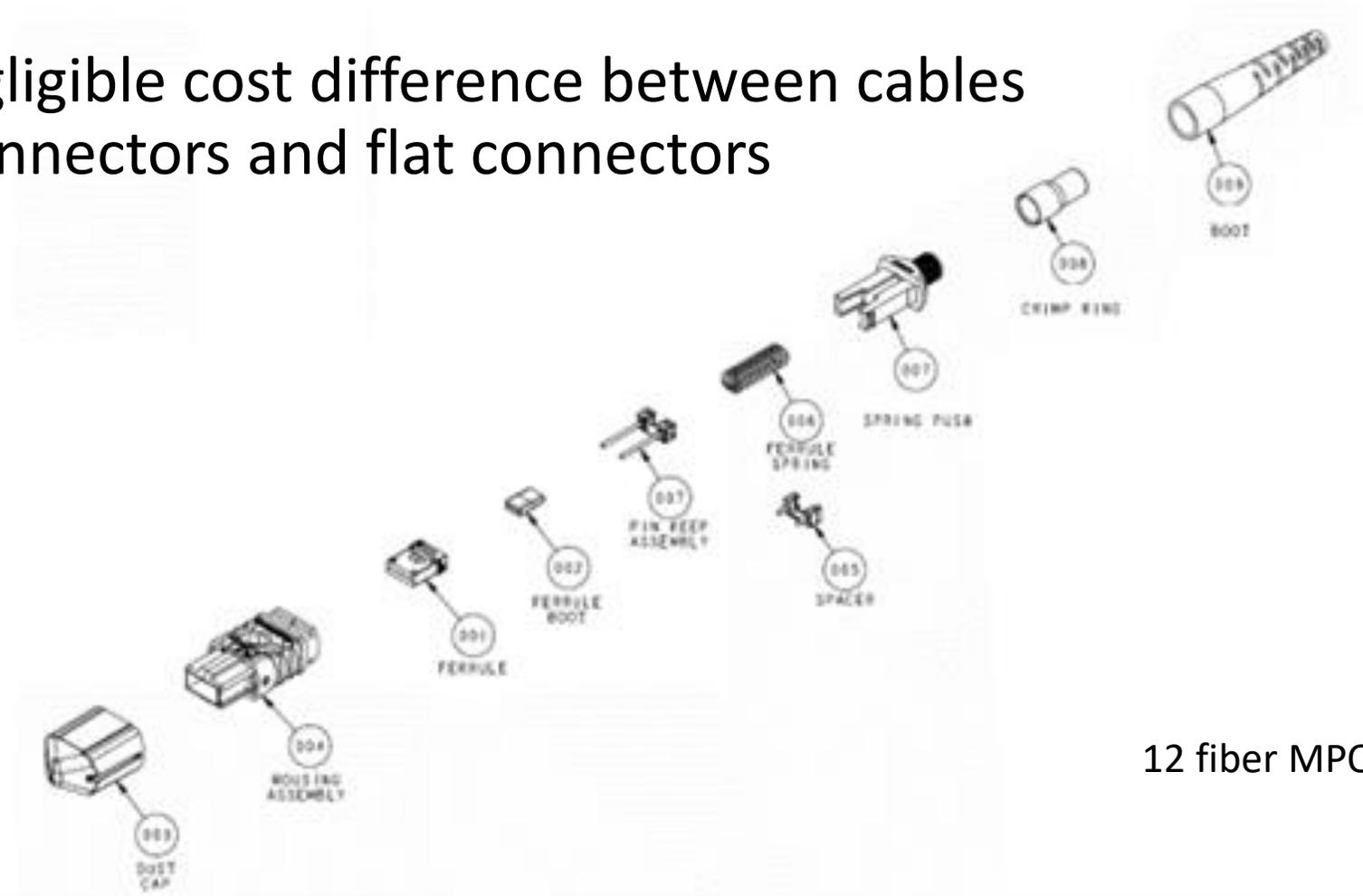
12 fiber MPO illustrated

APC connectors have higher RL values than UPC connectors, even when unmated
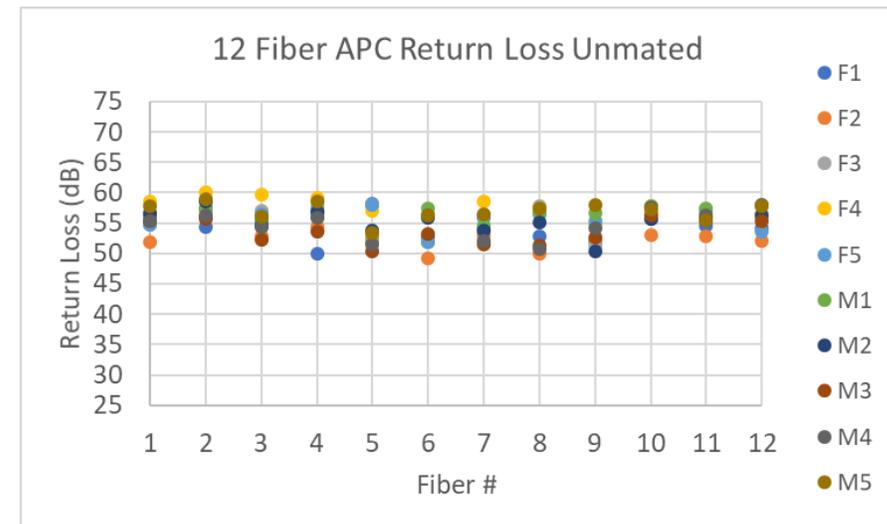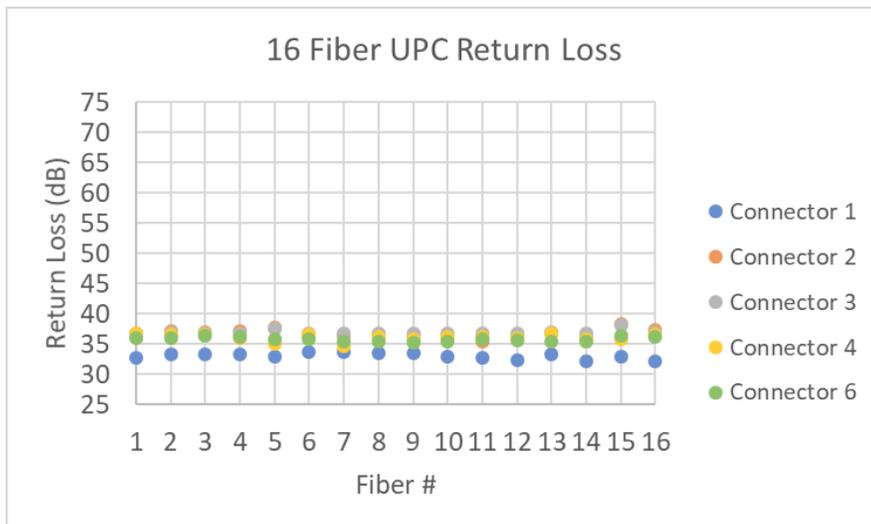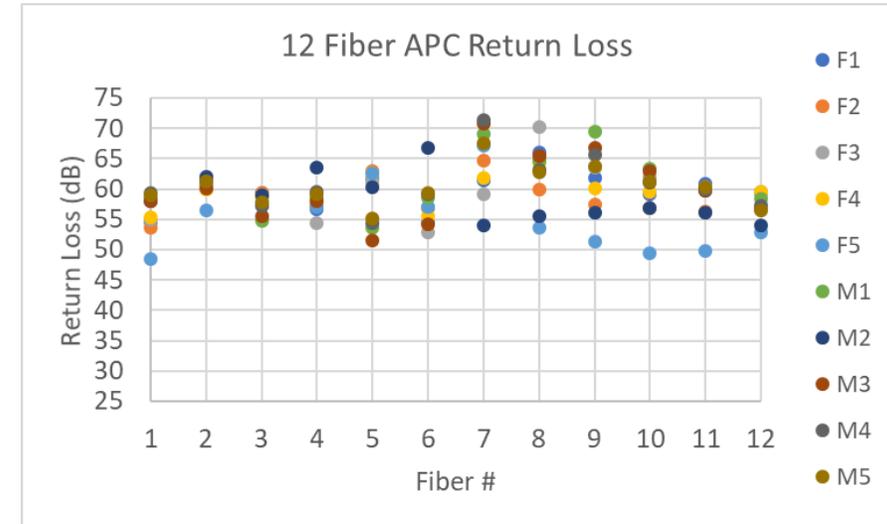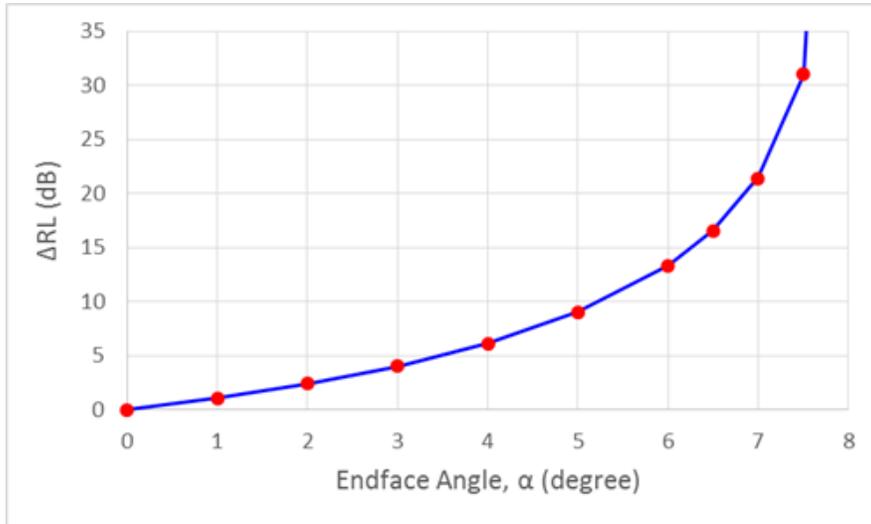
Experimental Setups
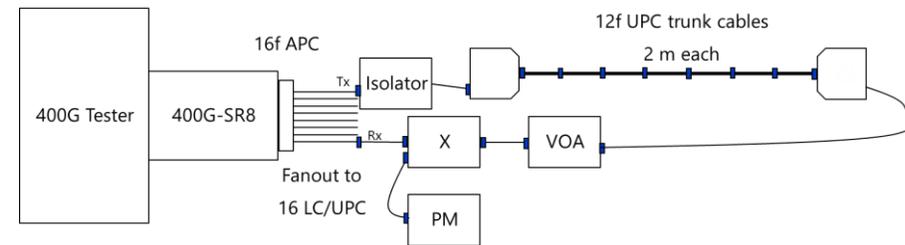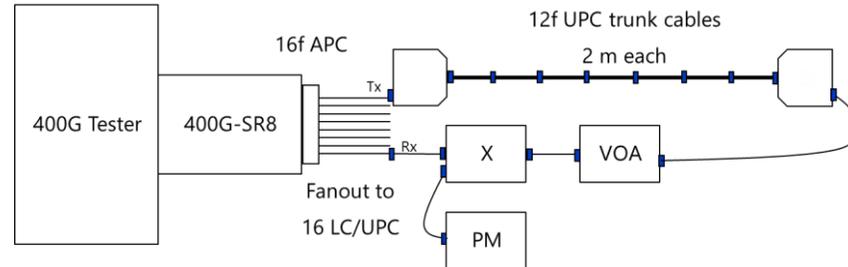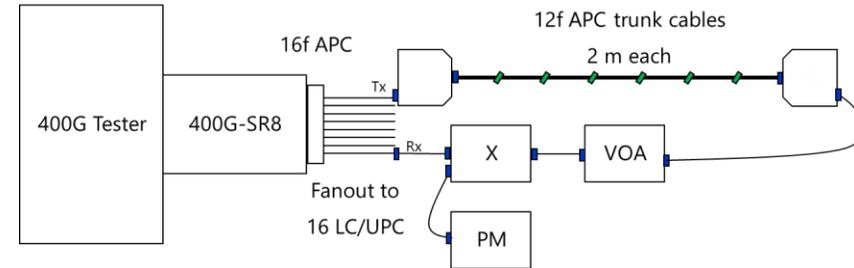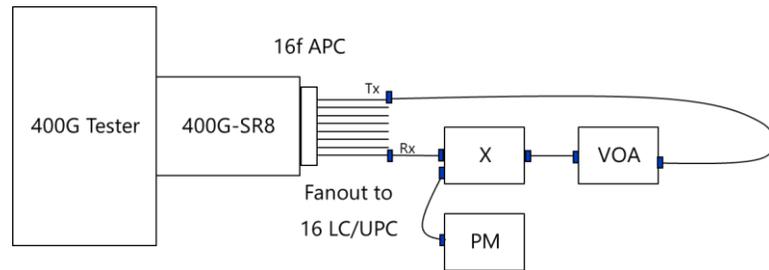
- PRBSQ31 pattern, 2-minute averaging interval
- Variable optical attenuator (VOA), switch (X) and power meter (PM)
- Same receiver used for all measurements
- Two sets of UPC cables:
  1. Clean connectors and compliant endface geometry
 2. One contaminated ferrule and two ferrules with x,y angle out of spec

Lane 0 transmission results
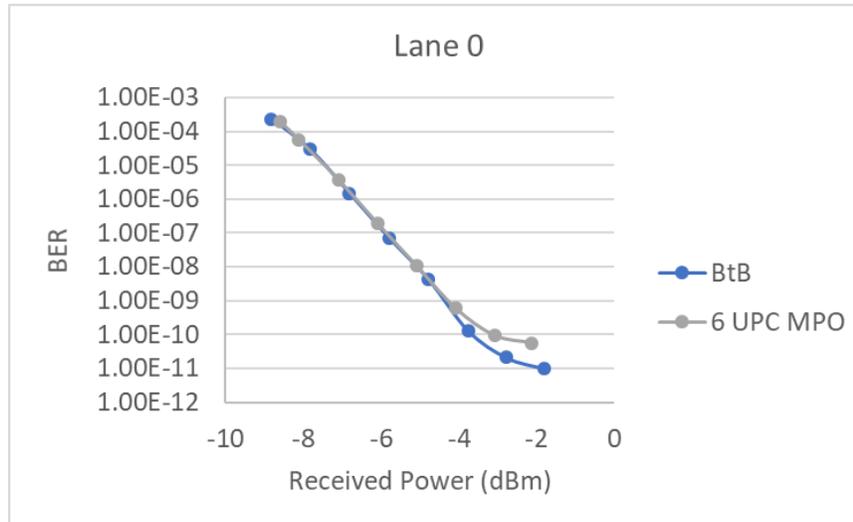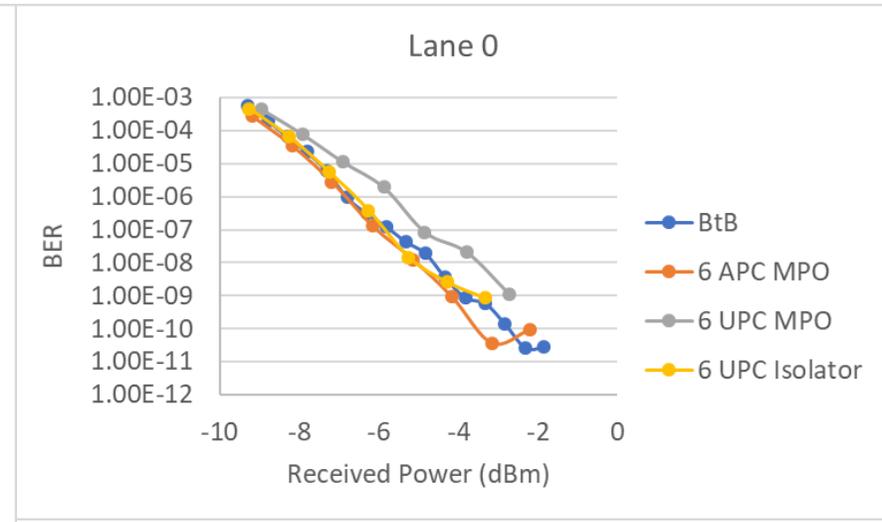
Controlled UPC

Problematic UPC

- No penalty from controlled UPC, APC connections
- Penalty for problematic UPC connections
- Isolator mitigates UPC penalty

Lane 1 transmission results
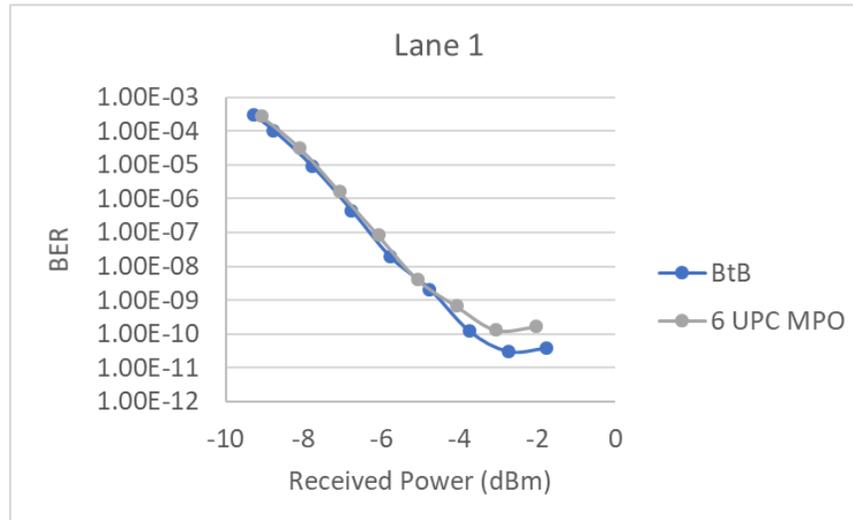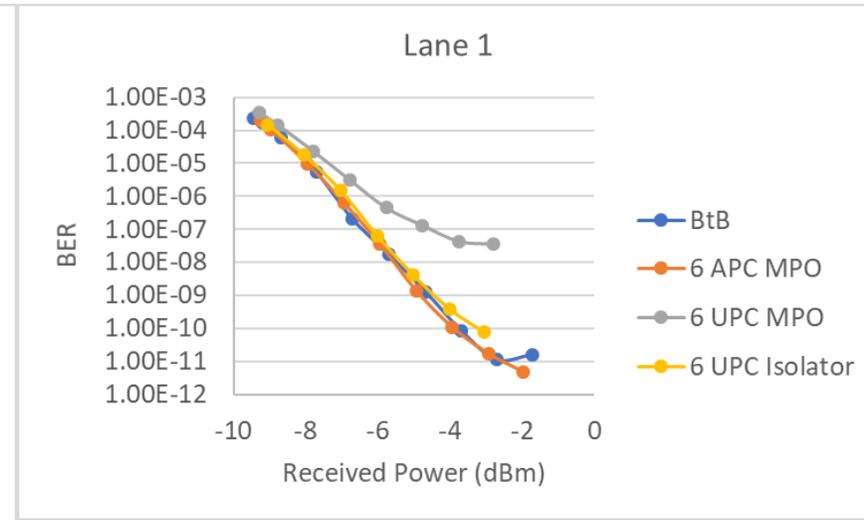
Controlled UPC

Problematic UPC

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Lane 2 transmission results
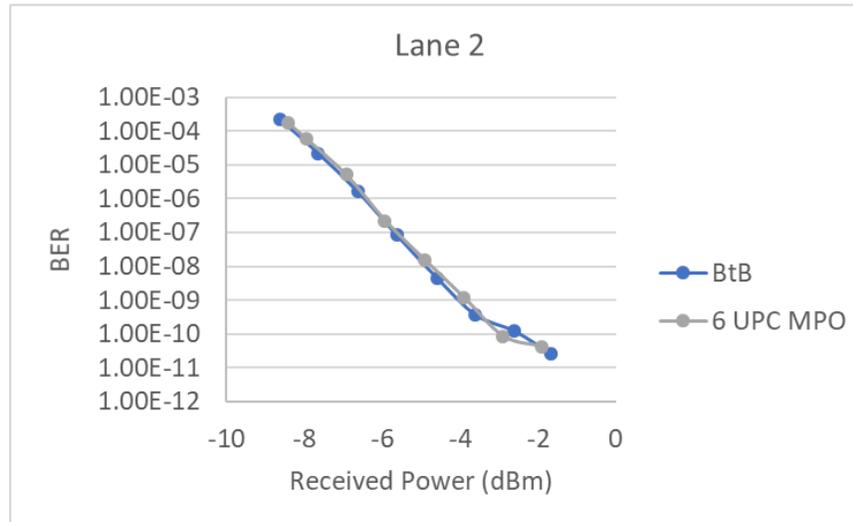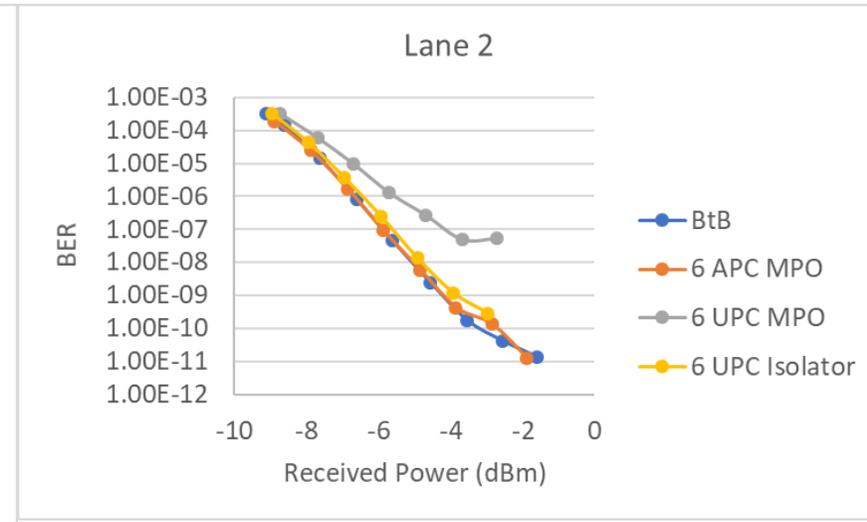
Controlled UPC

Problematic UPC

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Lane 3 transmission results
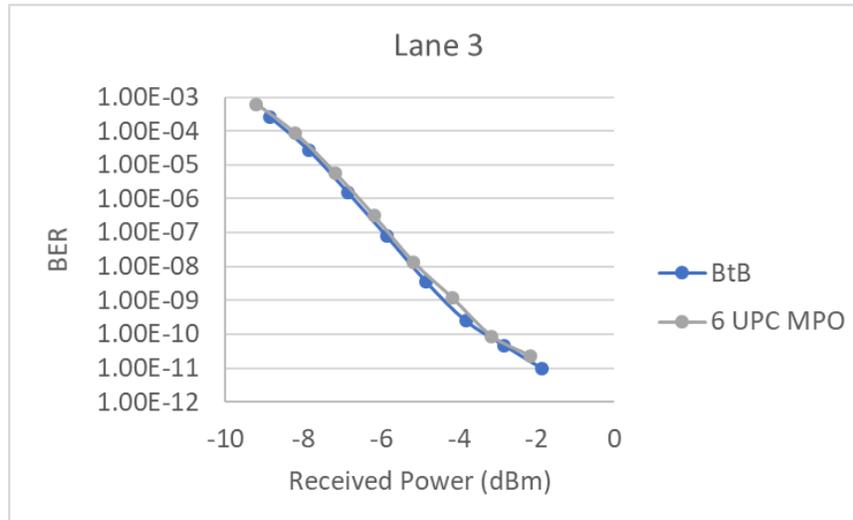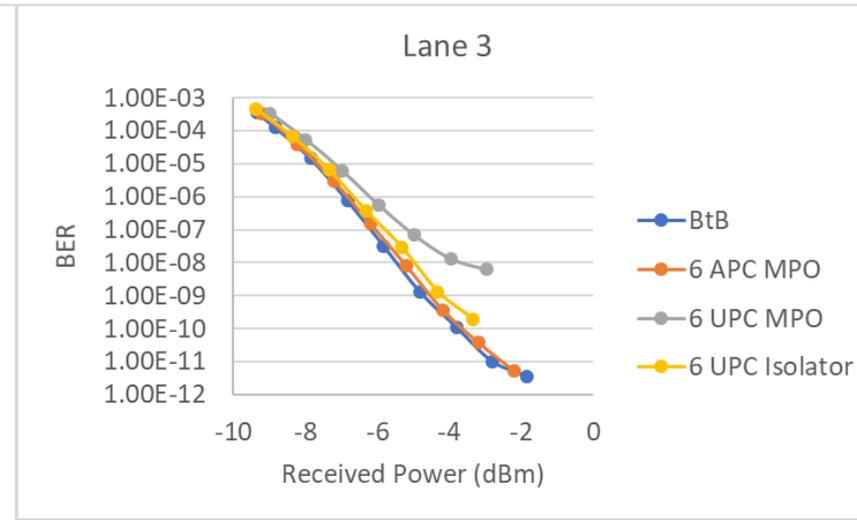
Controlled UPC

Problematic UPC

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The BER penalty scales with cumulative RL.
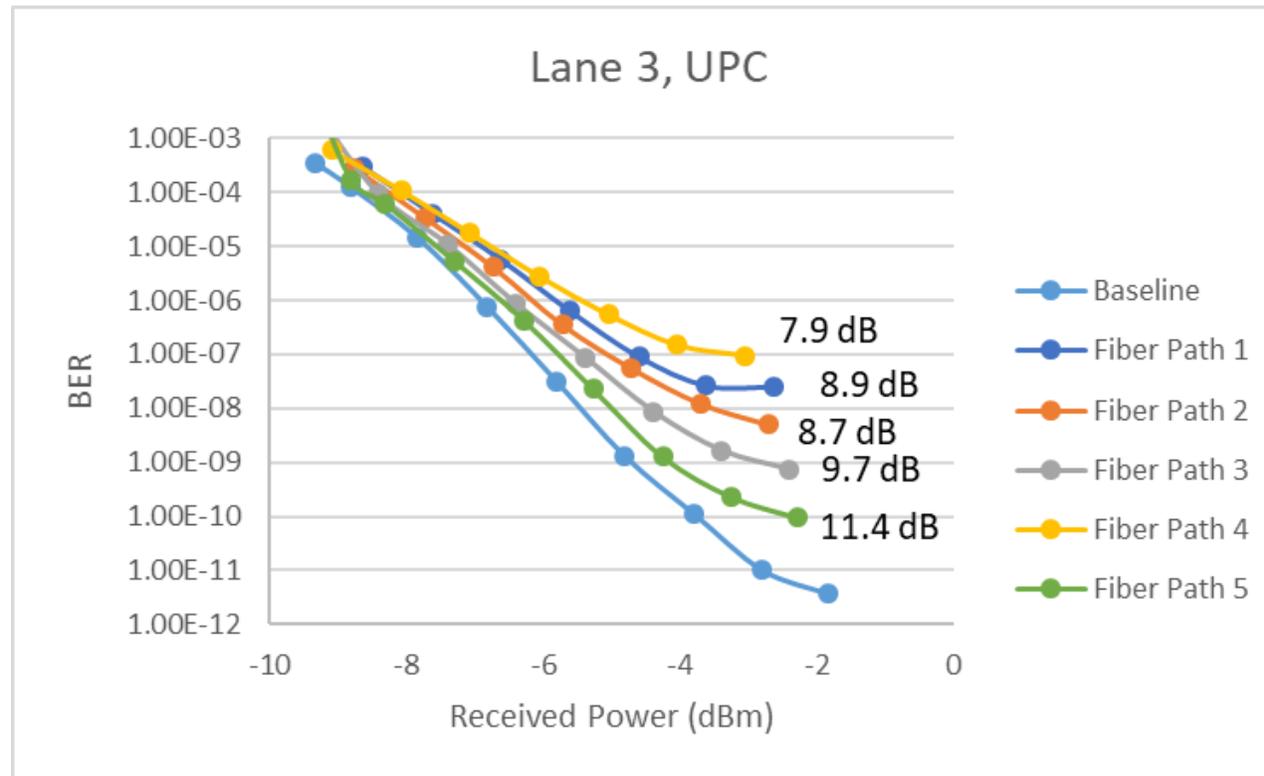
- Test single lane over different fiber paths with different RL values
- Very small penalty near 12 dB, the maximum reflectance spec

Conclusions

- Connector return loss impacts PAM4 signaling performance
- UPC connectors can be used if physical contact is maintained through
  - Cleanliness
  - Proper endface geometry
- UPC connectors with air gaps may introduce enough reflection to degrade system performance
- APC connectors offer higher return loss and may mitigate the risk of poor performance due to air gaps
- End users selected APC for 400G-SR8
- Recommend we allow APC in .3db